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13. ABSTRACT (Maximum 200 words)

This report results from a contract tasking Flerov laboratory for Nuclear Reactions as follows: The contractor will investigate hosts for emitting isomers that may be used in experiments for induced gamma-ray emission. He will define criteria to be used in selecting hosts and then prepare a list of suitable hosts to be used with isomers of interest.

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Photonuclear reactions on high-spin isomeric targets

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Abstract. Production of the new pure high-purity spin isomeric states is discussed. The most promising for the investigations isomers are selected. The first results of the deexcitation of ^{108}Ag (J^π=6$^-$) and ^{166}Ho (J^π=7$^-$) are presented.

Intradaction

Nuclear reactions with high-spin isomers are of interest for the investigation of nuclear structure effects. High-spin targets may have significant absorption cross sections in comparison with usual nuclei, due to the nuclear structure, possible alteration of deformation and nuclear radius, and also the level density of the compound nucleus. It is very important to establish the existence of some selective population of the levels in the residual nucleus with the structure similar to that of the initial nucleus. When the initial nucleus has a high spin, one may expect preferable population of high spin levels in the residual nucleus. The simplest method for obtaining the experimental information is measuring the transition probability from the isomeric to the ground state (the isomeric ratio).

The predominant number of experiments with bremsstrahlung γ-rays and heavy ions have been carried out, as a rule, on stable isotopes which have low ground state spins. Therefore, in photonuclear reactions, for example, the states are excited with spin values close to the ground state spin. The excitation mechanism of these photo nuclear reactions is very well known for most isotopes in the region of the Giant Dipole Resonance and these experimental results are reflected in review [1].

At present, only two stable isotopes, ^{180}Ta^m(J^π=9$^-$) and ^{176}Lu^m(J^π=7$^-$), are available as high-spin targets. For example, in the inelastic γ-quanta scattering on ^{180}Ta^m a relatively small number of activation levels, with the unusually large integral cross section value (0.35 mb.MeV), was observed [2]. In the region of the neutron emission threshold this integral cross section exceeds by about two orders of magnitude the values obtained at $E < 6$ MeV. Moreover, in this energy range, anomalously large isomeric ratios were obtained [3]. This isomeric ratio at the de-excitation of ^{180}Ta is practically the same as that of the excitation of the isomers with a small difference in the ground and isomeric states (ΔJ=3-4) [4].

However one may essentially extend the possibilities of these experiments if one uses a target of non-stable nuclei in isomeric states. The large de-excitation cross-section of these states in inelastic γ-quanta scattering allow one to hope for successful measurements of a small number of atoms (about 10^{15}) in experiments with isomeric targets [3]. The interest in nuclear reactions with high-spin isomers has been enhanced by the theoretical consideration of the K-mixing in excited nuclei and by the possibility for an efficient pumping process in the γ-laser problem.

The choice of producing reactions

We started with a series of investigations connected with the accumulation, mass-separations and gamma excitation of high-spin isomeric targets which are shown in the Table.

Table. Ground and isomeric characteristics of some nuclei which may be used as isomeric targets

Nuclear states		Energy keV	J^{π} $\hbar$	ΔJ^{π}	$T_{1/2}$	B_n MeV
^{108}Ag	m	109.5	6^+	5	418.25 y	7.27
	g	0	1^+		142.2 s	
^{166}Ho	m	5.0	7^-	7	1200 y	6.24
	g	0	0^+		26.8 h	
^{178}Hf	m2	2450.0	16^+	8	31 y	7.62
	m1	1147.4	8^-		4 s	
^{180}Ta	m	73.3	9^-	8	$1.2\cdot10^{13}$ y	6.55
	g	0	1^+		8.1 h	
^{186}Re	m	150.0	8^+	7	2.10^5 y	6.18
	g	0	1^-		90.6 h	
^{242}Am	m	48.6	5^-	4	152 y	5.54
	g	0	1^-		16.01 h	

Accumulation of these nuclei can be done on a power reactor. Sufficient cooling time allows the ground state of these isomers to completely decay, due to the short half-life. This kind of accumulation methods is very effective if one takes into account the big integral cross section for neutron capture. The necessary amount of radioactive nuclei can be produced using milligrams of initial samples. Separation of the isomers from the initial stable nuclide may be performed on a mass-separator. It essentially improves the experimental background conditions and allows one to obtain only isomeric targets. In the case of ^{178}Hf^{m2}, high energy α particles produced in the $(\alpha,2n)$ reaction may be used for obtaining large quantities of ^{178}Hf^{m2} nuclei [5].

Measurement runs

We started these investigations with accumulation of isomeric long-lived high spin nuclei of ^{108m}Ag ($J^{\pi}=6^+$) and ^{166m}Ho ($J^{\pi}=7^-$). In the first stage, it was necessary to to accumulate enough nuclei in isomeric states. For this purpose we irradiated 10 mg of natural sample of Ho on the neutron reactor IBR-30 at the Laboratory of Neutron Reactions, Dubna. After the (n,γ) reactions the isomeric state of ^{166m}Ho has excited. The gross sections of these reactions (3.5 b) is enough after 8 days irradiation with integral thermal neutron flux of 10^{18} n/cm to accumulated 10^{15} nuclei in isomeric states. The ground state of these nuclei are short-lived (26.8 h) and, after some days, its activity was completely disintegrated. The similar situation was with the activity induced by the (n,2n), (n,p) and (n,α) reactions. This activity is short-lived and soon completely disintegrates too. In that way, we produced 10^{15} nucleis of ^{166m}Ho. On the same reactor many years ago has been irradiated and natural sample of Ag. At present 10^{17} nucleus in ^{108m}Ag isomeric states have been accumulated. In the figure the γ-spectrum of isomeric the target ^{108m}Ag ($J^{\pi}=6^+$) obtained after (n,γ) reactions is shown.

It is possible to get a pure isomeric sample after mass separation. That means the ballast activity and the target elements will be eliminated after this procedure. At present mass separation ("YASNAPP" mass-separator at JINR, Dubna) is being performed for one of these targets (^{166m}Ho).

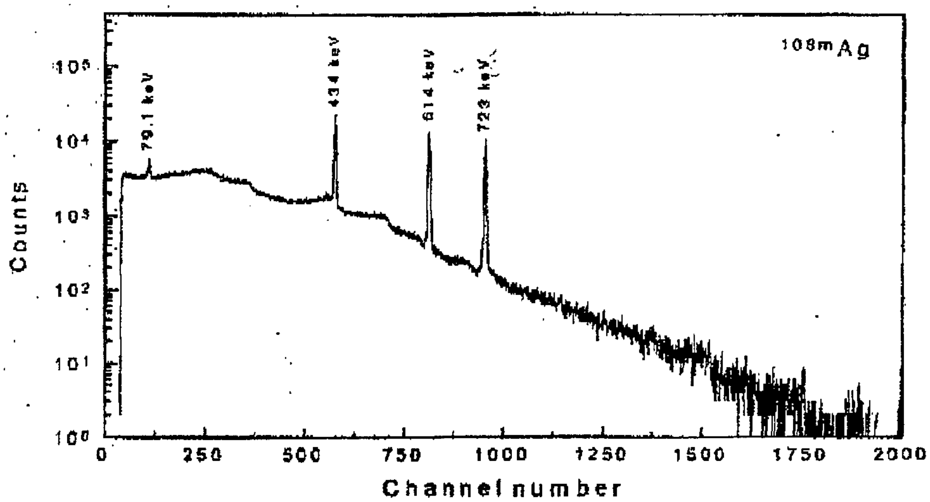

Fig. Spectrum of ^{108m}Ag γ-rays following neutron excitation of ^{nat}Ag. Cooling time (the time after the end of irradiation) is more then 13 years. Measurement time is 10 min. Number of nuclei in the ^{108m}Ag isomeric state with $J^\pi = 6^+$ is 10^{17}.

To observe the induced deexcitation of these two nuclides in the isomer state, gamma and beta spectrometers were utilized. Generally, gamma spectrometers register the yield of isomer state by measuring the gamma lines of the isomer transition or those after its beta-decay. However, the measured results thus obtained are influenced by the fact that the induced decay is superimposed on its permanent gamma-decay. In the case of holmium it is far more preferable to measure the spectra of the beta-particles of the isomer and ground states. For ^{166}Ho the energy of the beta-particles for the isomer and ground being respectively 0.065 and 1.855 MeV, the yield of ground state after the deexcitation of the isomer is easy to measure.

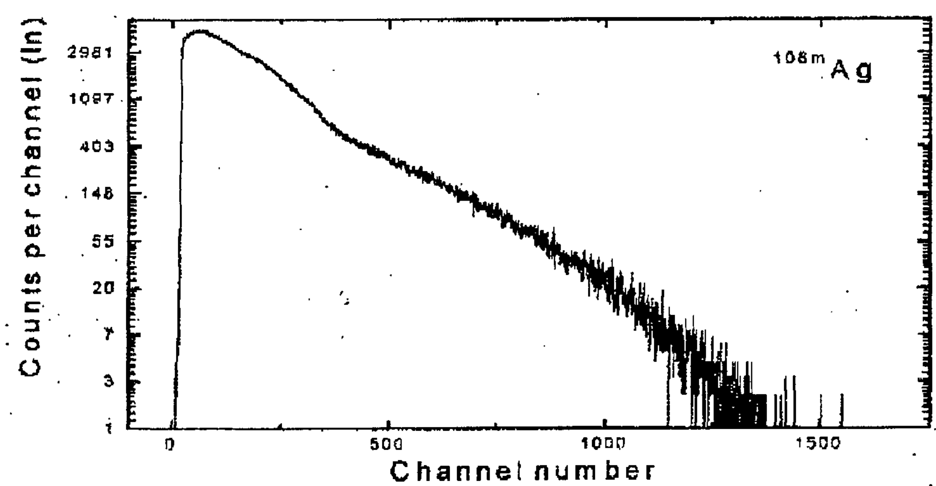

Fig.2. The measured beta-spectrum of ^{108m}Ag after being irradiated with 7 MeV gamma-quanta. The measuring time was 15 min.

Our experiments on irradiation of ^{108m}Ag and ^{166m}Ho have shown that at 7 MeV the integral inelastic scattering cross section is as high as that for the inelastic scattering by tantalum.

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